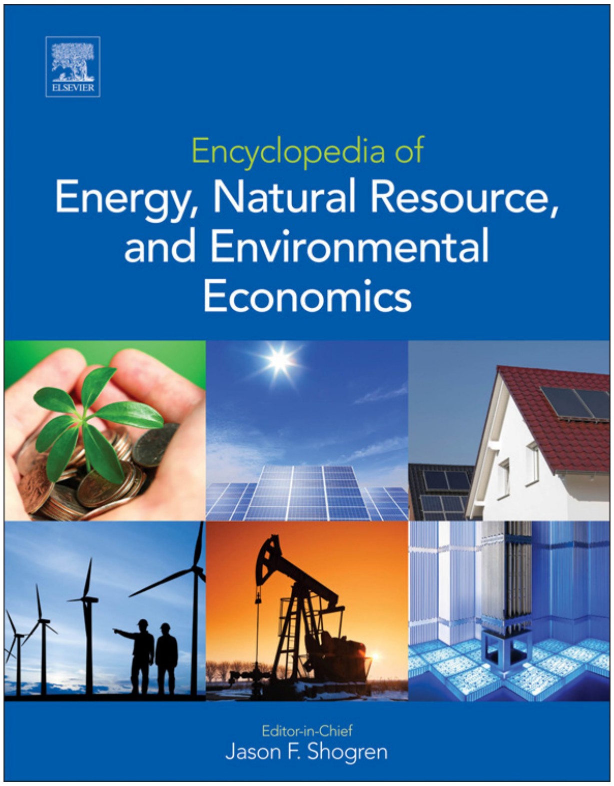

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Waste Disposal and Recycling

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Glossary

Dioxins A type of air pollutant harmful to humans, created by low-temperature incineration of solid waste.
Environmental Kuznets curve A theoretical relationship between national income and pollution generation that posits that pollution increases with income at low levels of income but then decreases with income at high levels of income.
Furans A type of air pollutant harmful to humans, created by low-temperature incineration of solid waste.
Green design A good is manufactured to promote easy reuse or recycling.
Green Dot program A form of environmental policy in Germany where manufacturers of beverages are made responsible for the collection and recycling of the waste generated from the consumption of those beverages.
Hedonic housing surveys A research tool that compares the value of properties located close to an environmental bad such as a landfill, with the value of similar properties located far away from the environmental bad. The difference in property values informs the estimation of the magnitude of the environmental bad.
Leachate A liquid created by the decomposition of solid waste in an oxygen-poor environment that can threaten area water tables.
Pigouvian tax An example of an incentive-based environmental policy whereby a tax, levied on the consumption or production of a good or service, is set equal to the external marginal cost generated by that good or service.
Single stream waste system A single truck collects the household's waste and transports it to a separation facility. Conveyer belts, magnets, blowers, and other technologies serve to separate various recyclable materials from the remainder of the waste stream.

Many environmental challenges facing the world today such as climate change, water and air pollution, and species endangerment are the consequences of the productive economy, of agriculture, land development, and industrial production. Solid waste is different. The consumer, not the firm, generates the bulk of solid waste. The waste consumers produce while at home or at work is unsightly, generates odor, threatens fresh groundwater supplies, and contributes to airborne dioxins. When looking for policies to improve things, consumers must examine their own choices and habits.

Economists promote incentive-based policy approaches to improve environmental quality at the lowest cost to the economy. Although cap-and-trade programs and environmental taxes appear sporadically across the environmental policy landscape, nowhere are incentive-based policies more common than in the market for solid waste. Thousands of municipalities across the globe require consumers to pay for each bag of waste contributed to collection agencies or subsidize consumer recycling efforts – both examples of environmental taxes. With the emphasis on consumers and on market-based policies, microeconomic theory and welfare economics are perfectly suited to study the market for solid waste and evaluate policy. The economics literature is rich in both empirical and theoretical observations and results from research.

This article summarizes the economist's view of solid waste disposal and recycling. To begin with, the next section discusses the historical development of solid waste management practices. This historical perspective sheds light on modern debates over how best to manage solid waste. These historical circumstances also describe current solid waste management practices in many developing countries.

Waste Management and Economic Development

The production of solid waste has been associated with human activity since the dawn of civilization. Throughout ancient history, the organic nature of most solid waste coupled with low human population densities made solid waste management a matter of little concern. Spent peels, rinds, and bones associated with food consumption could be buried to enrich soil, burned for cooking and warmth, or left for scavenging animals or for natural decomposition. Waste that did not decompose rapidly, such as clay ceramics and tools, could be discarded in out-of the-way pits that today serve as valuable archeological sites. Other household goods such as textiles and furniture were often repaired and reused rather than discarded. Thus, the waste discarded by any single individual mattered little to others. Lacking a substantial externality, the need to collectively manage solid waste was minimal.

Growing urban populations attributable to economic development changed things. Although the composition of the waste itself remained largely organic, the convenient destination for household waste became the urban street – where open dumping imposed obvious costs on others. Although scavenging animals might eventually remove the street waste, the public sought improvements. Households with sufficient income levels could pay others to transport their waste to an open dump site on the edge of the town. But if other households continued to dump in the street, then the associated external costs remained. Changing household street-based disposal habits formed the crux of early waste management policies. Eventually, municipal governments began to allocate tax revenues gained from growing economies to the provision of

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free waste collection to all households. Waste would be placed in collection bins either in front of each residency or at a centralized neighborhood location. These first collection programs were likely crude and disorganized. Collection was sporadic, and waste would overflow the available containers. Providing efficient and organized municipal collection along established and scheduled routes remains a challenge in many urban areas in developing parts of the world even today. Rather than following specific routes, waste collectors collect waste wherever they may find it. Weeks can pass between collections in some neighborhoods.

But cleaning up the streets brought a new policy challenge – what was to be done with all the collected waste? And, to make matters worse, all efforts extended toward cleaning urban areas by consistently scheduling free collection, reduced the household's cost of waste disposal, which tended to increase waste generation. Economic development also ushered in rising household incomes, the emergence of industrial production, and household consumption of products made of inorganic materials such as plastics, paper, and various metal alloys. The combined effect was a substantial increase in solid waste quantities. Urban planners were taken by surprise as available landfill spaces filled rapidly. Odors, disease, unsightliness, and a preponderance of scavenging animals elevated solid waste management to a substantial public concern. The 'throwaway' culture was born.

This new challenge of managing large quantities of urban waste was addressed by several policy strategies. First, the growing quantities of waste could be transported to dumping sites located farther away from human urban populations. The cost of this alternative could be relatively small – once waste was loaded onto a collection truck, the marginal cost of transporting the waste a few additional miles for dumping in remote lands was comparatively low. Waste could be transported by truck, rail, or barge across vast distances and even to other neighboring countries. The number of individuals located within close proximity to open waste decreased. Solid waste in the United States, for example, is often transported hundreds of miles from high to low population density regions.

A second policy response was more costly. The emergence of a taste for environmental quality (perhaps linked to rising incomes) made large open dumps, even in remote locations, unpalatable to the rising middle class. Central governments responded by implementing new technology-based standards to reduce the environmental damage associated with solid waste disposal. The Resource Conservation and Recovery Act passed in 1976 in the United States is one such example. At a minimum, these new standards required that waste be covered each day with sand or soil thus reducing odor and disease from scavenging animals. But covering waste removed oxygen from the natural decomposition process. Decomposition in an oxygen-poor environment resulted in the creation of leachates, a liquid that threatens area water tables, and methane, a gas that contributes to climate change.

Rather expensive processes are required to minimize the external costs associated with leachate and methane production. Leachate collection systems require the base of a new landfill to be lined with several feet of impermeable clay or with rolls of heavy plastics. A network of collection pipes must be placed throughout the landfill to collect the leachate for treatment using filtering technologies such as reverse osmosis. A network of pipes must also be installed to collect methane, which can then be burned to generate electricity. A large landfill can generate electricity sufficient to power a small town. The modern landfill in many developed nations includes both leachate and methane collection systems, but waste in many developing nations remains either uncovered or covered without the use of these technologies.

Third, the large costs associated with modern landfill operations have encouraged municipal governments in many developed nations to implement incineration. Incineration is particularly common where land values are high such as in Japan, the Netherlands, and in Northeastern United States. Incineration can be economical in developed nations because the composition of waste includes plastic and paper – both easily combusted. Waste in developing countries contains large quantities of organic materials such as food waste that are high in moisture content and therefore difficult to burn. Although incineration solves many problems associated with open dumping, new external costs associated with poor air quality emerge. The first incinerators featured relatively low burning temperatures and consequently emitted both dioxins and furans – chemicals hazardous to human health. Increasing the burning temperature reduces these external costs but increases the operating costs.

Finally, many developed nations have also allocated economic resources to reducing the quantity of waste destined for landfills or incinerators. The most common method for doing so is the introduction of municipal recycling opportunities. At a minimum, municipal governments establish a location for residents to cart recyclable materials such as paper, glass, plastics, and metals. Or the municipality could initiate curbside collection of these materials. But municipal recycling is expensive. Recycling a ton of waste is about twice as expensive to the municipality as disposing or incinerating that ton. Thus, like incineration, recycling may not be an option in developing countries where household incomes are low.

For curbside or drop-off municipal recycling programs to reduce waste, millions of households across a nation must begin to separate recyclable materials from their waste streams. Such a major shift in disposal behavior was last observed when households began to utilize waste containers rather than the open streets to dispose waste. That shift involved very little additional effort on the part of households – setting the waste container for curbside collection on the appropriate day was not terribly more difficult than dumping in the street. Has the transition toward recycling been as easy? Empirical evidence suggests that it has not. Household participation in curbside or drop-off recycling programs has consistently been estimated to be less than one hundred percent. Apparently, the costs of households to separate, store, and possibly transport recyclable materials to the curb or drop-off center are large enough to discourage the practice. Just as street dumping was convenient in prior years, convenient and free waste collection practices are easy for modern households. Changing household practices may therefore require public policy to either increase the household's cost of disposing waste or decrease the costs of recycling or composting. These policy alternatives are discussed in more detail in the following sections. The next section summarizes the current data available on waste generation and recycling in developed countries.

Recent Data Trends

The Organization for Economic Co-Operation and Development (OECD) gathers and maintains data on the quantity of municipal solid waste generated in each of its member countries. Per capita generation of solid waste ranges between a high of 35 pounds per week in Norway to about 5 pounds per person in China. Other countries producing large per capita quantities of municipal waste include Switzerland (30 pounds per person per week), Denmark (34), Ireland (33), and the United States (32). In addition to China, OECD countries producing relatively low quantities of waste include the Czech Republic (12 pounds per person per week), Mexico (15), Canada (17), and Japan (17). These differences can be attributed to differences in income, demographic characteristics, and consumption habits.

The OECD also forecasts an increase of 1.3% in per-capita quantities of municipal solid waste per year between 2011 and 2030. Annual increases are estimated to be 1.5% in Europe, 1.3% in the Americas, and 1.1% in Asia. These increases in municipal solid waste generation quantities are attributable to increases in population (expected to grow at a 0.4% annual rate between 2011 and 2030 in all OECD countries) and increases in real income (2.3%).

The statistical relationship between income and per capita waste generation has consistently been estimated to be positive. For example, in separate studies, a 1% increase in income has been estimated to increase waste generation by 0.46% in less developed nations in the Caribbean, by 0.34% among all nations of the world, and by 0.18% among developed OECD countries. When considering these estimates, it appears that income and solid waste generation begins to become decoupled at high levels of income. Perhaps the share of income spent on services increases with income, and services generate less waste than product consumption. Developed nations can also afford expensive recycling and composting programs.

If one accepts the notion that solid waste quantities are decoupled from income, the subsequent question is what level of income might solid waste generation actually decrease with additional levels of income? In other words, at what income level does one reach the height of the Environmental Kuznets curve (the economist Simon Kuznets had originally studied the decoupling of income levels and income inequality)? Imagine a country so wealthy that any additional income stimulates technologies and consumption habits that serve to reduce waste. Estimating that level of income involves a great deal of conjecture. One study using income and solid waste data gathered only from Japanese municipalities suggests that this income level is about $600 000 per year – increases in income levels above this threshold are predicted to decrease waste generation. Assuming annual real income increases of 2%, this level of income should be reached in a few centuries by developed economies of today. Therefore, for the foreseeable future, governments of developing economies should plan to tackle rising waste quantities.

Recycling has become commonplace in many developed countries. The percentage of waste recycled increased from miniscule amounts to 20% or 30% in the 1980s and 1990s in the United States, Europe, and parts of Southeast Asia. But differences exist in the recycling quantities across developed nations. Germany, Finland, and Japan, for example, recycle nearly 80% of glass waste and 60% of paper. The United States, Ireland, Italy, and Portugal recycle only 20–40% of these two materials. Differences in recycling rates can be attributed to differences in household income and to policy measures that encourage recycling. Germany's Green Dot program, for example, is responsible for very large recycling rates of glass. Recycling in developing countries is less advanced. Deposit–refund programs provide incentives for the recycling of beverage containers in many developing countries, but curbside collection of plastics, paper, and glass is very rare across the developing world.

External Costs and External Benefits

Even modern solid waste landfills and incinerators generate environmental costs. Both facilities involve a constant stream of trucks depositing waste. These trucks add to congestion on local roadways and cause air and noise pollution. At landfills, the growing mountain of waste can emit odors, and the oddly shaped garbage hill can be unsightly. Any leachate that breaches the base of a covered landfill threatens area groundwater supplies and, potentially, human health. Incineration generates air pollution, especially in the form of dioxins, and ashes that require disposal. Researchers have placed monetary values on the magnitudes of these external costs, and this section discusses these estimates. A related area of research investigates the external benefits of recycling generated as manufacturers who use recycled materials in production require less energy and generate less air and water pollution than those using virgin inputs.

Much of what people know about the magnitude of the external costs associated with waste disposal originates from hedonic housing surveys conducted primarily in the United States and from two reports published by the Department for Environment, Food, and Rural Affairs (DEFRA) in the United Kingdom. Hedonic housing surveys compare the values of properties located within close proximity to a disposal facility with home values farther afield. Collectively, these studies suggest that landfills reduce the value of properties located between one-fourth and one-half of a mile from the landfill by between 21% and 30%. Property values then increase from these low levels by between 5% and 8% with each mile in distance from the landfill up to 4 miles. Landfills are not estimated to decrease the value of properties located more than 4 miles away. Using these estimates and applying plausible assumptions related to (1) the number and value of properties within 4 miles of a landfill, (2) the quantity of waste disposed over the lifetime of the landfill, (3) the number of years the landfill actively receives waste, and (4) the discount rate, these hedonic estimates suggest that each ton of solid waste generates between $3 and $4 of external costs. Because incinerators pose a greater threat to human health than landfills, the external costs of incineration, also based upon hedonic housing studies, have been estimated at between $20 and $30 per ton. These higher external costs are attributable to airborne releases of dioxins and furans.

Landfills and incinerators also impose external costs on populations beyond the neighbors located within a 4 mile radius. In parts of the United States, waste can be transported hundreds of miles for eventual disposal in a remote rural landfill. As mentioned above, waste collection and transportation trucks congest roadways, increase the likelihood of accidents, deteriorate roads, and generate air pollution. The DEFRA report mentioned earlier estimates that each ton of waste transported to an urban landfill or incinerator generates about 35 cents of external cost due merely to the generation of air pollution and the increased threat of roadway accidents. These external costs roughly double when transporting waste to a rural landfill. Landfills and incinerators also emit climate change gasses. Carbon dioxide and especially methane are emitted from landfills. The DEFRA report estimates that the external cost associated with these emissions is $4 per ton. This external cost can be cut roughly in half if the landfill utilizes technologies to capture the methane to generate electricity. When considering the fact that electricity generation from landfills reduces the need for coal and oil, the climate change portion of external costs associated with landfills with methane capture falls to about zero. By combining these separate external costs, each ton of waste disposed in an urban landfill with methane capture is estimated to generate about $3.75 in external costs. That same ton of garbage transported to a rural landfill without methane capture is estimated to generate almost $9 in external costs.

Recycling solid waste not only reduces the external costs of disposal but also generates external benefits across manufacturing regions of the economy. Manufacturers who utilize recycled materials over virgin materials generate less air and water pollution and require less energy than those who use virgin materials. Only a few studies have attempted to estimate these external benefits. Although estimates vary across these studies, all agree that the external benefits of using recycled aluminum are the highest ($850–1770 per ton), followed by steel and paper ($70–225 per ton), glass ($15–190 per ton), and various plastics (−$5 to –$50 per ton). These results can be combined with those mentioned above to estimate the overall nonmarket benefits of recycling over the benefits of disposing each product. For example, each ton of recycled paper used in production reduces the external costs of disposal by as much as $234.

These external costs and benefits distort market choices over how to efficiently dispose waste and employ production materials. Policy measures are therefore necessary for consumers and firms to make socially optimal choices. The next section discusses available policy options.

A Summary of Policy Approaches and the Related Empirical Literature

Consequent to both the external costs associated with waste disposal and the external benefits associated with the provision of recyclable materials, the free market collection and disposal market will produce too much solid waste and too little recycling. A Pigouvian tax set equal to the external marginal cost of waste disposal coupled with a recycling subsidy on each recyclable material would lead to efficient quantities. These instruments can be assessed at many points along the waste stream. Consumption taxes, advanced disposal fees, and producer responsibility measures such as Germany's Green Dot program are examples of upstream policies. For these three policy approaches, the external costs of disposal are paid at the time of consumption. Consumers internalize the full social costs of their purchases and rationally make purchases only if the marginal utility of consumption exceeds both the private and external marginal costs of production and eventual disposal. The results are efficient consumption decisions. But upstream policies lead to efficient disposal choices only if (1) consumers are presented with only one disposal option or (2) all available disposal options involve identical external costs.

Consumers in many developed nations face two primary disposal choices for recyclable materials – to present these materials as waste at the curb for collection and landfill disposal or for collection and recycling. As discussed above, the external costs associated with these two decisions are not identical. Thus, the three upstream policies discussed above will encourage consumers to choose too much waste and not enough recycling. Policy measures farther downstream that either tax garbage or subsidize recycling are necessary.

The curbside recycling program implemented by many municipal governments in developed countries serves as one example of a recycling subsidy. Although not a monetary subsidy imagined by many economic models, that the municipality will collect, transport, process, and market recyclable materials at no marginal cost to the household represents a rather substantial in-kind subsidy. Economies of scale in these services make a sole municipal (or private franchise) operation economically efficient.

Economic models suggest that any recycling subsidy must be accompanied by a consumption tax to achieve the efficient allocation of economic resources. Without the small consumption tax, the subsidy by itself can inefficiently increase consumption. Municipal governments that combine curbside recycling subsidies with state or local sales taxes may therefore be acting efficiently. A deposit–refund program also satisfies the condition for efficiency. The deposit serves as the consumption tax, and the refund subsidizes the recycling (the return).

Rather than subsidizing recycling, a second policy approach is to tax the household's waste generation. Under a pay-as-you-throw policy, households must purchase specific bags, tags, stickers, or cans in order to be eligible for municipal waste collection services. The price of each container of waste can therefore be set equal to the external marginal cost of disposal to achieve efficient disposal quantities. The disposal tax can be assessed either at the curb or farther downstream at the landfill. As is the case with all relative upstream policies, the curbside tax will be efficient only if collectors face either one disposal option (the landfill) or identical external costs for many disposal options. If, for example, collectors can deposit collected waste at either a centralized recycling facility or a landfill, then the curbside tax will distort efficient disposal decisions of collectors.

Assessing a landfill or incinerator tax – at the point of final disposal – represents the farthest downstream a policy can go. Downstream policies eliminate the inefficiencies associated with multiple options discussed earlier. Downstream policies such as landfill and incineration taxes can vary with respect to the external costs associated with each disposal method and are therefore efficient. Downstream policies can also be relatively easy to administer when compared to taxing households at the curb or taxing consumption. Downstream policies also result in optimal consumption decisions at the top of the stream. A landfill tax increases the cost of disposal and therefore increases the implicit price of waste-intensive goods.

The major drawback of downstream policies such as curbside or landfill taxes arises when households face a third option for waste disposal – the possibly illicit and illegal practice of littering or burning solid waste. Recall that free and convenient curbside waste collection was historically necessary to discourage households from disposing waste in the street. Taxing waste reverses household disposal incentives, and economic research has found evidence of unwelcome disposal habits in the wake of curbside taxation. If the external costs of litter and illegal dumping exceed those associated with landfill disposal, and if illegal disposal cannot be taxed, then optimal policy requires a subsidy on both garbage and recycling collection. Free and convenient collection of waste and recycling may be optimal.

While offering free and convenient collection of recyclable materials is possible, subsidizing household recycling efforts can be administratively costly. As discussed earlier, the external benefits of recyclable materials vary across materials. Optimal policy would therefore require a unique subsidy paid for the provision of each material. External benefits of recycling are realized in manufacturing regions and are therefore rarely internalized by the municipalities when setting curbside policy. Lacking the resources to administer recycling subsidies and the incentives for doing so, most municipalities choose to offer households free collection and nothing more.

Speculating on the Future

Technological developments will likely continue to shape the future of solid waste management and recycling. One can only speculate on the nature of these new developments. One technology already implemented in some developed economies is a single stream waste system. This system requires no effort on the part of the household other than preparing all waste – that which can be recycled and all the rest – for collection in a single bin. A single truck collects the household's waste and transports it to a separation facility. Conveyer belts, magnets, blowers, and other technologies serve to separate various recyclable materials from the remainder of the waste stream. Recycling rates can be expected to rise even as curbside policies such as pay-per-bag programs and separate recycling collections discussed earlier become unnecessary. Although single stream waste systems are still rare, single stream recycling systems – where households separate all recyclable materials from waste and the recyclables are then separated from each other at the centralized facility – are common in many developed countries today.

One can also expect incineration plants to generate less dioxin and other airborne pollutants in the future. The latest incinerators developed in Japan, a country that incinerates almost all of its solid waste, provide a hint as to what future incinerators may look like. Increasing combustion temperatures to over 8500 degrees centigrade virtually eliminates air pollution. Keeping temperatures at such high levels will require the injection of fossil fuels and large quantities of solid waste. The latter requirement is met in Japan, where large population densities provide ample trash to economically justify the high fixed costs of incineration. Incinerators in Tokyo are located throughout the city. Tall chimneys are designed creatively to be architecturally attractive. To appease the closest neighbors, the incinerators provide free access to exercise facilities, and few complaints are received. Although expensive to operate, such incineration technologies may also be appropriate in other densely populated regions such as New York City and parts of Europe.

Improvements in green design may also shape the future of waste and recycling. Manufacturing products to generate little waste or improve the recyclability will diminish the external costs of disposal. New forms of plastic, for example, can be manufactured to naturally decompose. Consumer electronics can be manufactured in such a way as to reduce the costs of extracting toxic materials at the time of disposal. Opportunities to improve the green design of automobiles, household appliances, packaging materials, and other consumer goods could redefine the treatment of waste in the future.

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